

# **Ocean Dynamics**

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## **LONG-TERM GOALS**

To gain a more complete understanding of ocean dynamical processes, particularly at fine-scale, through intercomparison of high, mid- and low-latitude observations, both near the sea surface, in the main thermocline, and near the sea floor.

## **OBJECTIVES**

To identify the phenomena involved in the cascade of energy from mesoscales to turbulent scales. To quantify the relationship between fine-scale background conditions and the occurrence of microscale breaking.

## **APPROACH**

Progress is effected through a steady-state cycle of instrument development, field observation and data analysis. The primary instruments employed include Doppler sonar and profiling CTD's. Generically, our instruments produce information which is quasi-continuous in space and time. Measurements typically span two decades in the wavenumber domain. This broad band space-time coverage enables the investigation of multi-scale interactions.

## **WORK COMPLETED**

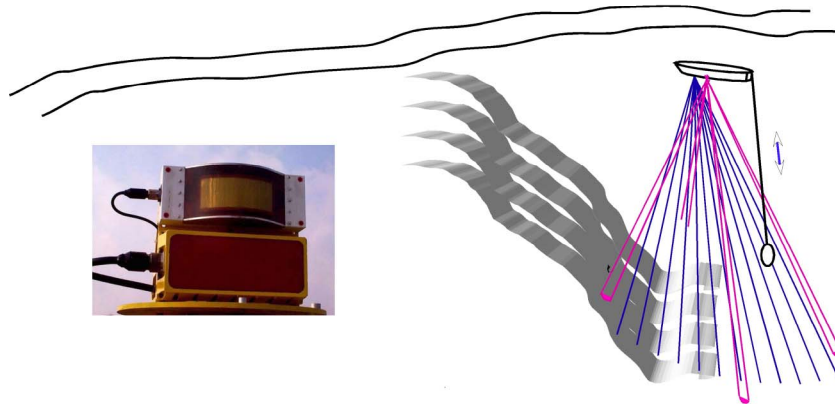
Preparations are under way for a 2005 cruise on the R/V Revelle to the S. China Sea to study the deep-water solitons generated in the Luzon Strait (Figure 1). These are reputed to be the largest solitons ever observed. The gross form of the soliton train can significantly refract sound, affecting both communications and surveillance. Given recent ONR efforts in shallow water (ASIAEX, PRIMER, etc.), the acoustic effects of the solitons should be predictable if we can document their form (sound speed anomaly) adequately. Also, the waves represent a significant velocity and buoyancy perturbation that can affect the trim of slowly moving underwater vehicles. The study of the interaction of the waves and their background and the documentation of observed dissipation and scattering should greatly advance our understanding.

The experiment is presently planned for April 2005. The field program is strongly constrained by a boundary imposed by the US Department of State (Figure 2 a,b), limiting the westward mobility of the Revelle. There is concern that strongly nonlinear waves will not have time to form in the allotted observation region. There is recent reason for optimism, however. The spring 2004 SAR image (Figure 2a), graciously provided by Dr. C.T. Liu, shows evidence of internal wave activity in the allotted

domain. If the boundary point at 20 degrees, 20°N, 120 E, were moved northward, the opportunity to observe wavefield development would be greatly enhanced.

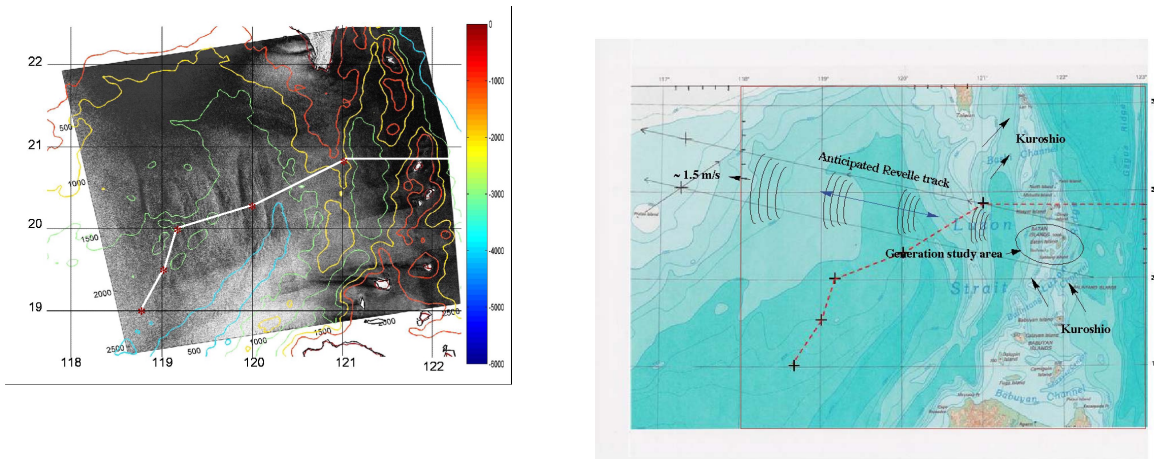
**Issues:**

Quantify Sea-Surface Strain Rate  
 Quantify Surface Wave Response  
 Quantify Acoustic Signature of Turbulence  
 [ form 3-d movies (x,z,t or y,z,t)]  
 Document Shear, Stability, Vertical Strain



***Figure 1. Schematic of the S.China Sea Soliton Experiment. The R.V. Roger Revelle is equipped with downward profiling 140 and 50 kHz Doppler Sonars, as well as a 16 beam 195 kHz vertically directed swath mapping sonar. A CTD is profiled at 3.5 m/s from the surface to ~400m. The ship moves at the phase speed of the waves, documenting the evolution of the packet. The inset photo is the 195 kHz 16-beam swath-mapping sonar that will be deployed through the well on the Revelle, producing  $(r, \theta, t)$  movies of the acoustic scattering field.***

The present straw-man plan is to depart Taiwan and steam for the extreme westerly edge of the allotted observation area, as defined by the State Department, to search for signs of internal nonlinear wavetrains. If these are detected, we will steam eastward ~120 km, then reverse and cruise westward with instruments deployed, attempting to track the evolution of the internal tide into a non-linear wave. Key points of evolutionary interest include the crossing of the east wall of the Kuroshio (Figure 5) and the “surface arrival point” of the initially downward propagating tidal ray emanating from Luzon Strait. In the Bay of Biscay, solitons were seen to form at this offshore point by New and Pingree (1990). More recent numerical studies suggest that nonlinear waves will form independent of this vertical energy convergence. We hope to determine what the “triggering” influence is on the propagating wave, or whether one is really necessary.



**Figure 2**

*a) A Synthetic Aperture Radar image of the S.China Sea provided by Dr. C.T.Liu. Bottom contours are indicated in color. The white line depicts the State Department determined boundary for Revelle operations. Evidence of nonlinear wave activity is seen in the allowable search area, although the most active area appears to the north.*

*b) A chart of the region depicting the assigned research area and the schematic propagation path of the most energetic non-linear waves, as suggested by Dr. S. Ramp. The SAR image provides a more optimistic indication that energetic waves will be seen in the research area.*

## RESULTS

Major effort has gone into the development of a portable, rapid-profiling (~8 kt vertical speed) instrument system that can be used from a slow moving/ stationary ship. The system is built around a SBE-49 CTD with an added fast-response conductivity probe. The profiling fish is suspended from a thin Kevlar fiber cable which is intended to survive  $\sim 10^4$  repeated profiles without failing.

## IMPACT/APPLICATIONS

If successful the fast-profiling instrument system will have broad applicability in physical, biological, and acoustics research. The rapid collection of profiling data from a sensor that is decoupled from the sea surface is a capability previously available only on FLIP. Hopefully, the new system will increase flexibility and decrease the cost of coming ONR field programs.

## RELATED PROJECTS

The ONR ASIAEX Program.

## PUBLICATIONS

Alford, M.H., R. Pinkel, 2000: Observations of overturning in the thermocline: The context of ocean mixing. J. Phys. Oceanogr., 30, 805-832

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Halle, C.M. and R. Pinkel, 2003: Internal wave variability in the Beaufort Sea during the winter of 1993/94. *J. Geophys. Res.* 108,C7,3-1 to 3-26

Rainville, L., and R. Pinkel, 2004: Observations of energetic high-wavenumber internal waves beneath the Kuroshio. *J. Phys. Res.* 34, 1495-1505.